Overview of Current ARM Cloud Parameterization and Modeling Activities, Data, and Plans

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Outline

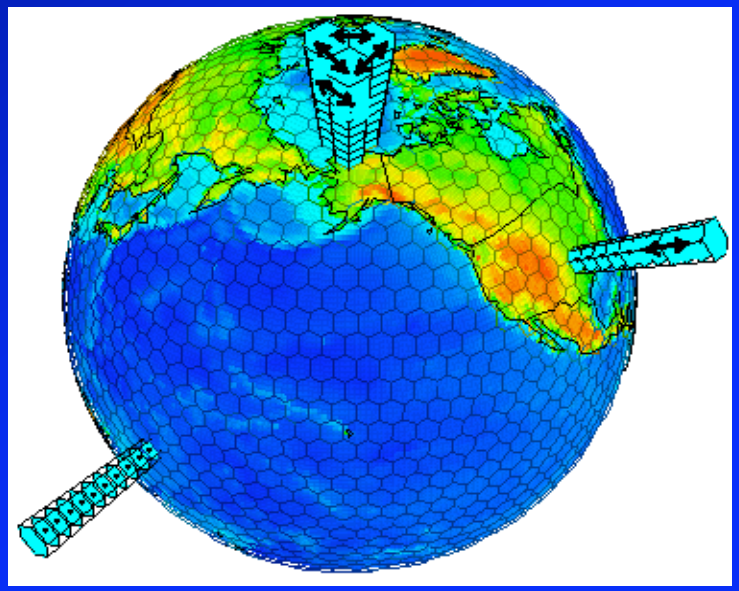
- SCM & CRM Forcing Data Sets for ARM Intensive Observing Periods (IOPs) at the Southern Great Plains site and selected results from their use
- "Continuous" Forcing Data Sets and selected results from their use
- Broad-Band Heating Rate Profile (BBHRP) project
- Future ARM IOPs and the ARM Mobile Facility

ARM goals

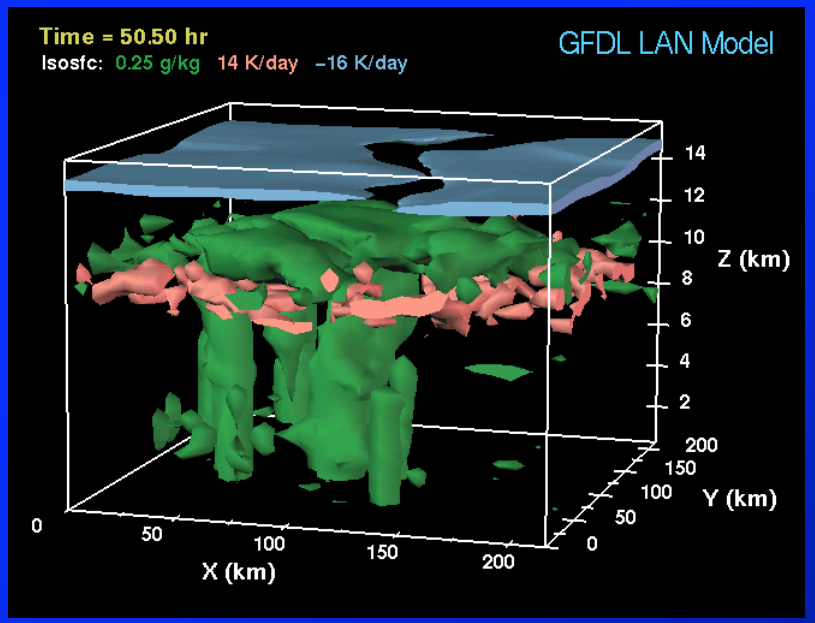
- A broad goal of the ARM program is to improve the simulation of clouds and their related processes through the detailed analysis of ARM data and Cloud Resolving Models

- The technique we have focussed on is the simulation for selected ARM IOPs by Cloud Resolving Models (CRMs) and Single-Column-Models (SCMs) driven by ARM data

Single Column Model (SCM)



Cloud Resolving Model (CRM)



The SCM/CRM Forcing Approach

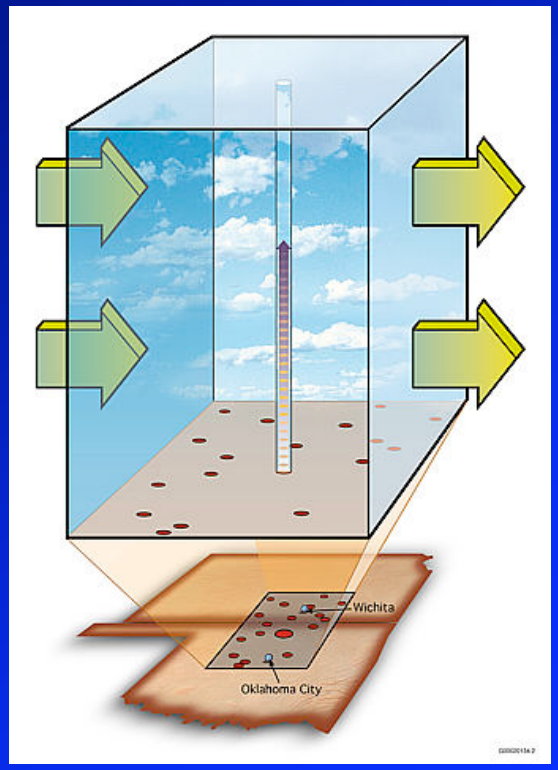
"Advective Forcing" computed from observations

"Physics" computed from:

- **CRM "explicitly"**
- **SCM parameterizations**

$$\frac{\partial s}{\partial t} = \boxed{-V \bullet \nabla s - \omega \frac{\partial s}{\partial p}} \; \boxed{+ L(c-e) - \frac{\partial \overline{\omega' s'}}{\partial p} + Q_{rad}}$$

$$\frac{\partial q}{\partial t} = \boxed{-V \bullet \nabla q - \omega \frac{\partial q}{\partial p}} \; \boxed{+ \quad (e-c) - \frac{\partial \overline{\omega' q'}}{\partial p}}$$



ARM Data During IOPs

- 5 sounding stations
- 7 wind profilers
- Dozens of surface flux and radiation estimates
- Surface observations from Oklahoma and Kansas Mesonet
- Precipitation estimates from radar
- TOA satellite estimates (Minnis et al.)

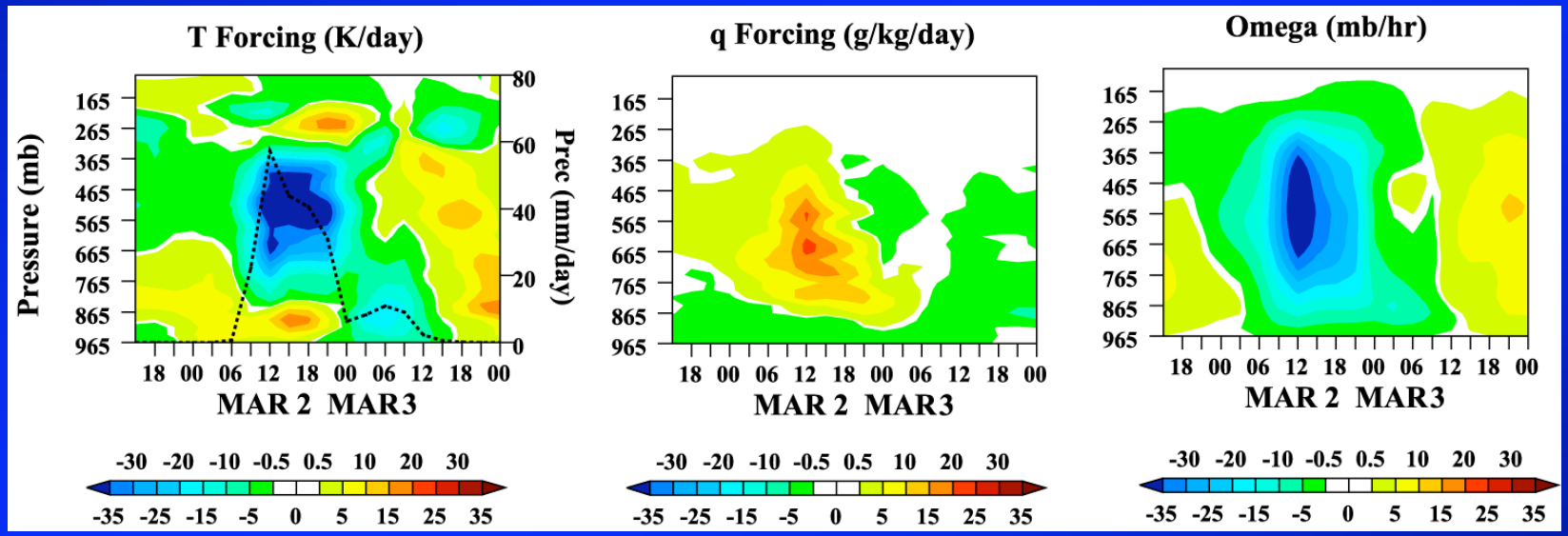
+ NCEP Regional Model (RUC) background fields

Variational Analysis *(Zhang and Lin 1997, Zhang et al. 2001)*

The profiles of state variables are adjusted until they satisfy column budgets of mass, energy, and moisture

Forcing Example

Strong Frontal Passage, March 2-3, 2000



IOPs Analyzed *(and data available for…)*

- **Summer: 1995, 1997, 1999, 2002**
- **Fall: 1997, 2000, 2002**
- **Winter: 1999, 2000**
- **Spring: 1997, 1998, 1999, 2000**

A total of ~250 days

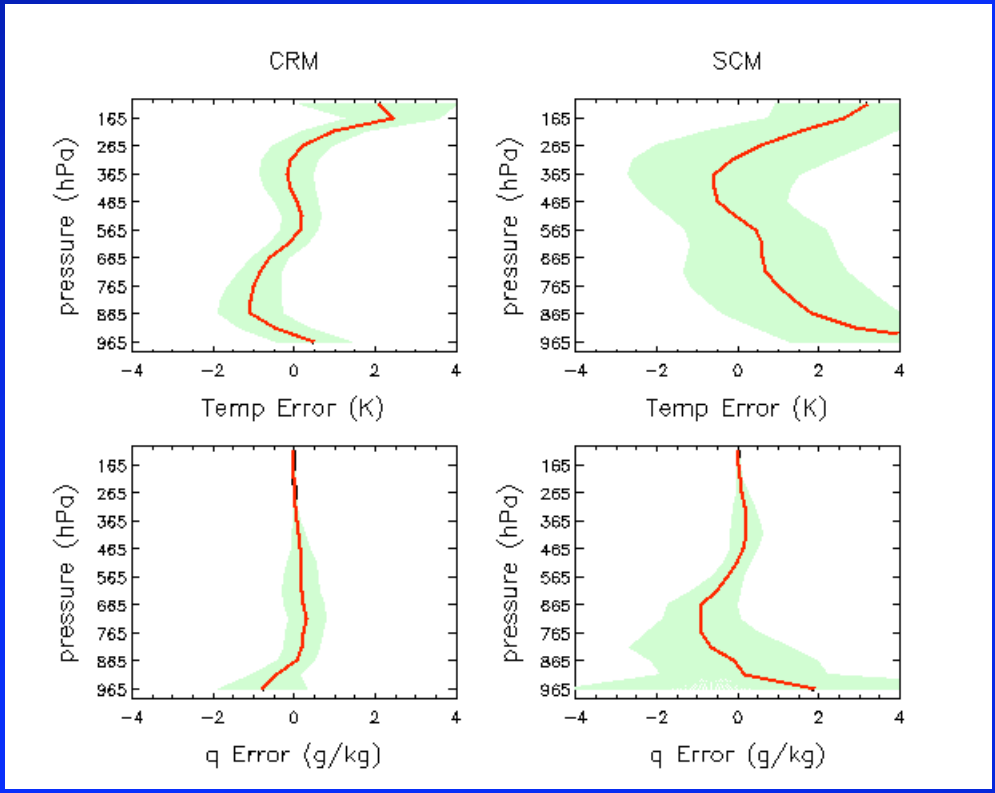
Two IOPs have have been intensely studied

- **Case 3 - June-July 1997 – Summer Deep Convection**
- **Case 4 - March 2000 – Spring Frontal Clouds**

Case 3 Results

(Xie et al. 2002, Xu et al. 2002)

Case 3 mean T and q errors for 10 CRMs and 11 SCMs

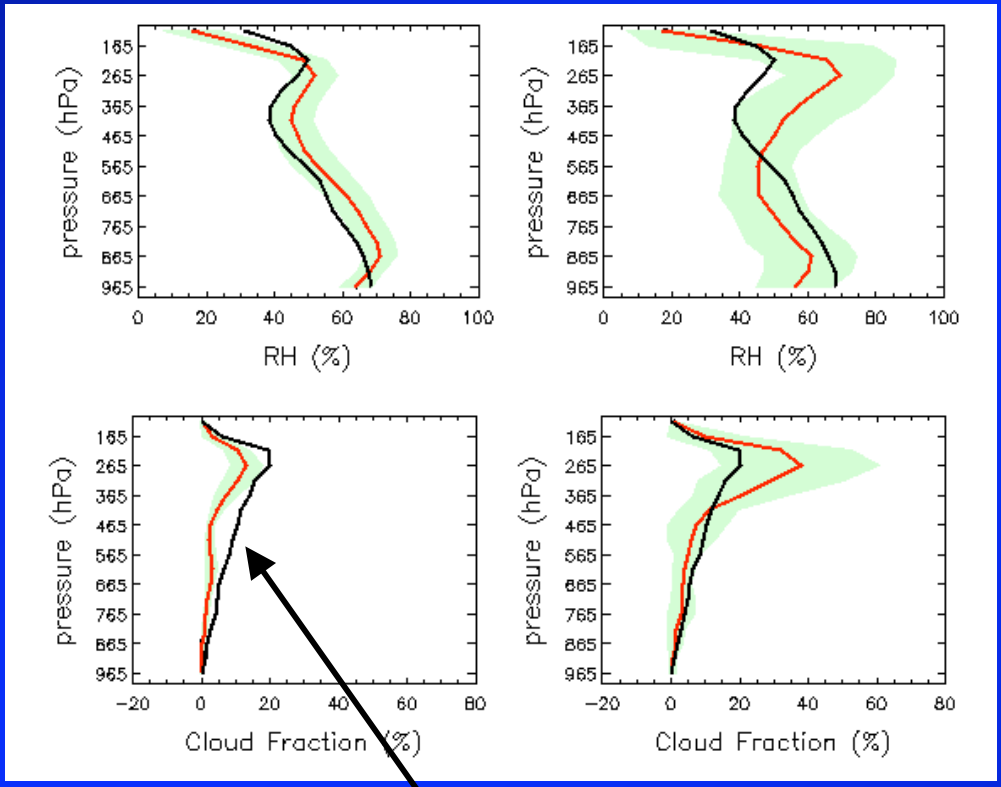


CRMs produce less bias and less scatter than SCMs (they should!)

Root mean square errors are also less.

Case 3 Relative Humidity and Cloud Fraction

CRMs **SCMs**

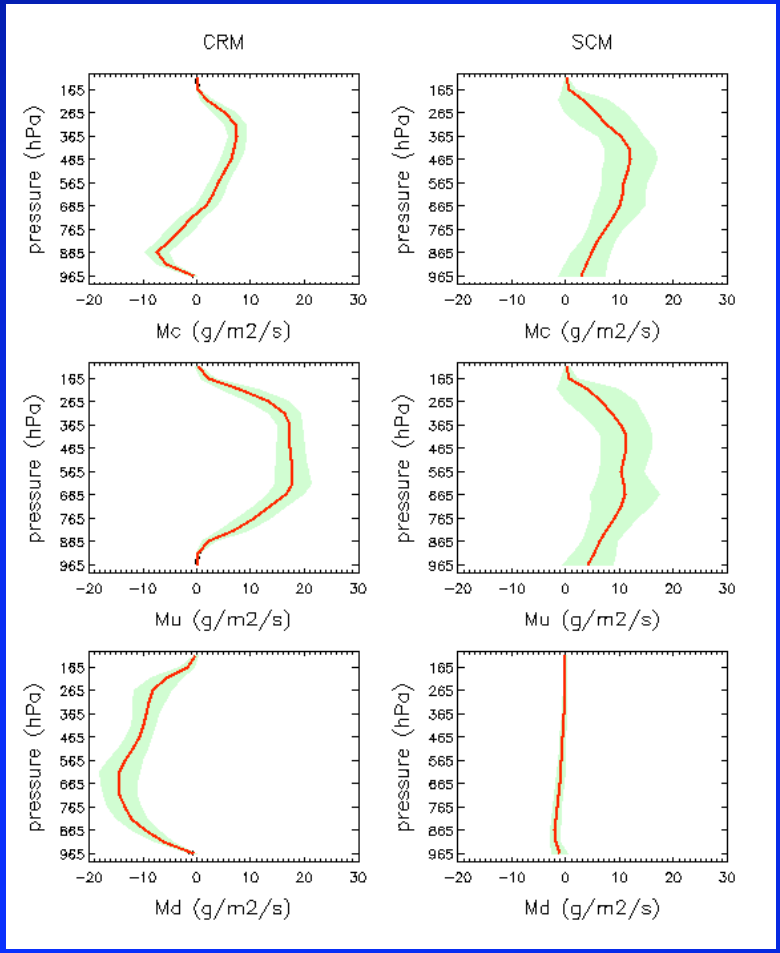


ARM Cloud Radar Observation

CRMs maintain a better relative humidity and cloud fraction structure

SCMs are too moist in relative humidity and associated cloud aloft

SCM errors may be caused by a lack of downdrafts



Net cumulus mass flux

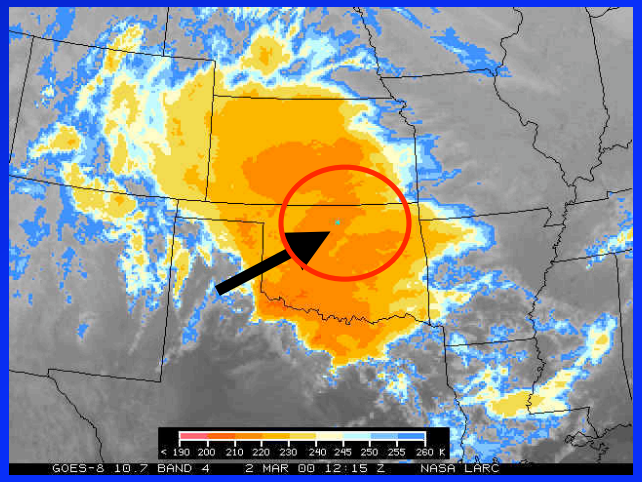
Updraft mass flux

Downdraft mass flux

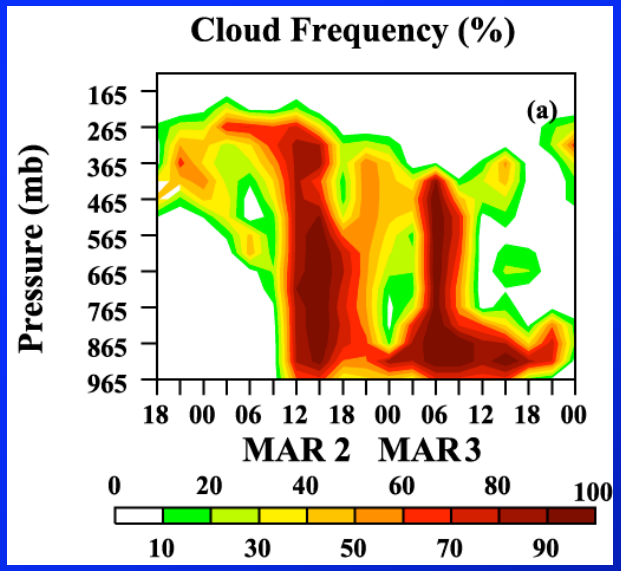
Case 4 Results

(Xie et al. 2005, Xu et al. 2005)

Strong Frontal Passage – March 2-3, 2000



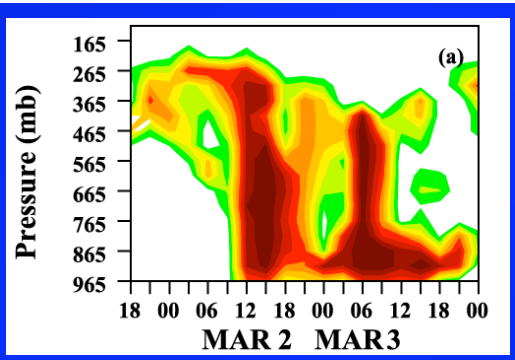
IR Image, 12Z March 2



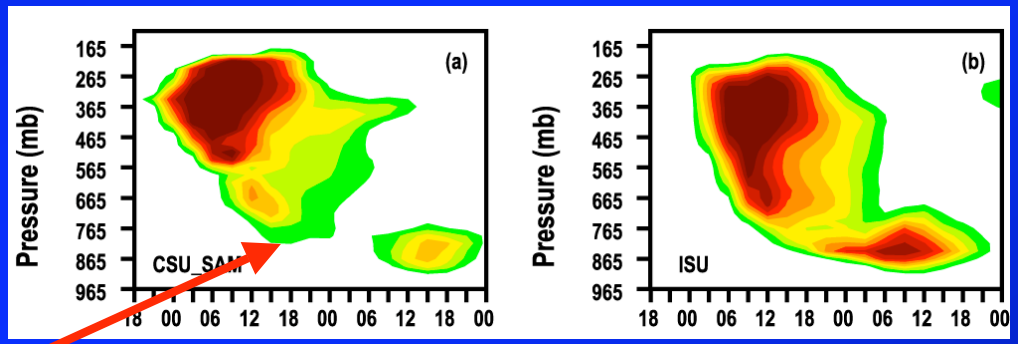
ARM Cloud Radar Observation

Cloud Fraction

Observation



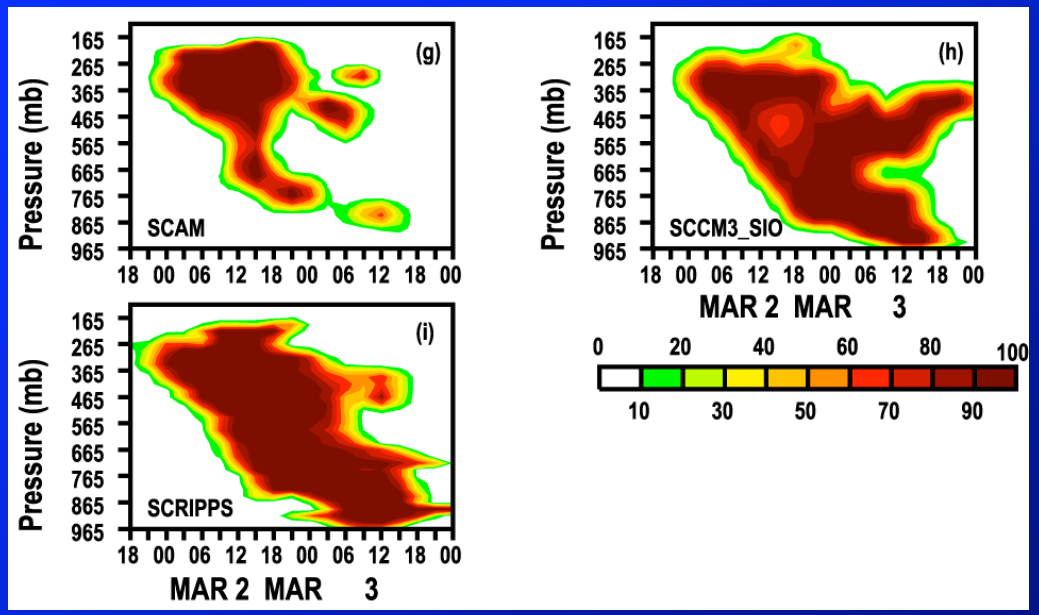
Selected CRMs



CRM clouds miss low level clouds

CRMs are too "convective"

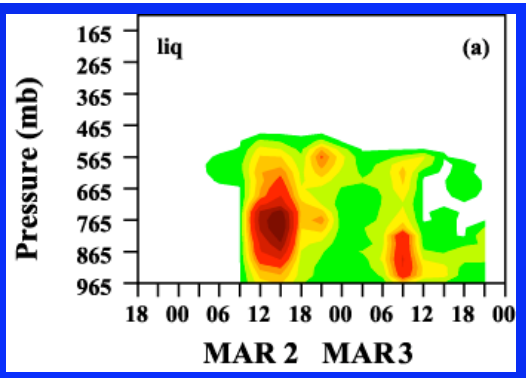
Selected SCMs



SCM clouds are too extensive

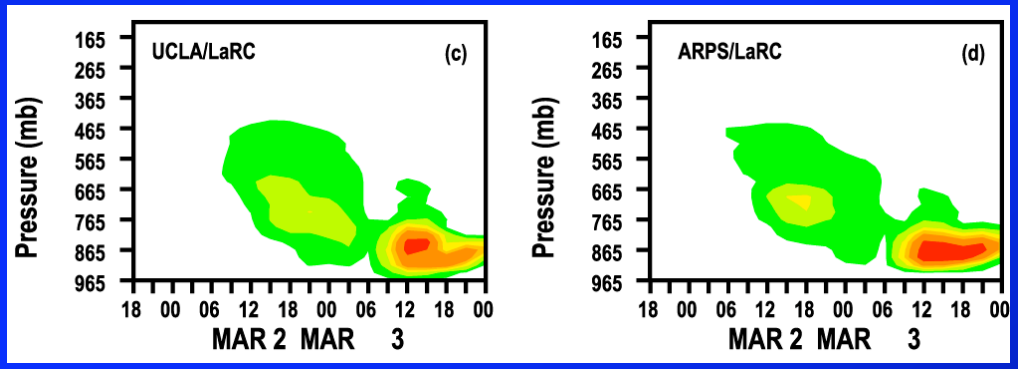
Cloud Liquid

Observation



'Microbase' analysis courtesy of Mark Miller et al.

Selected CRMs



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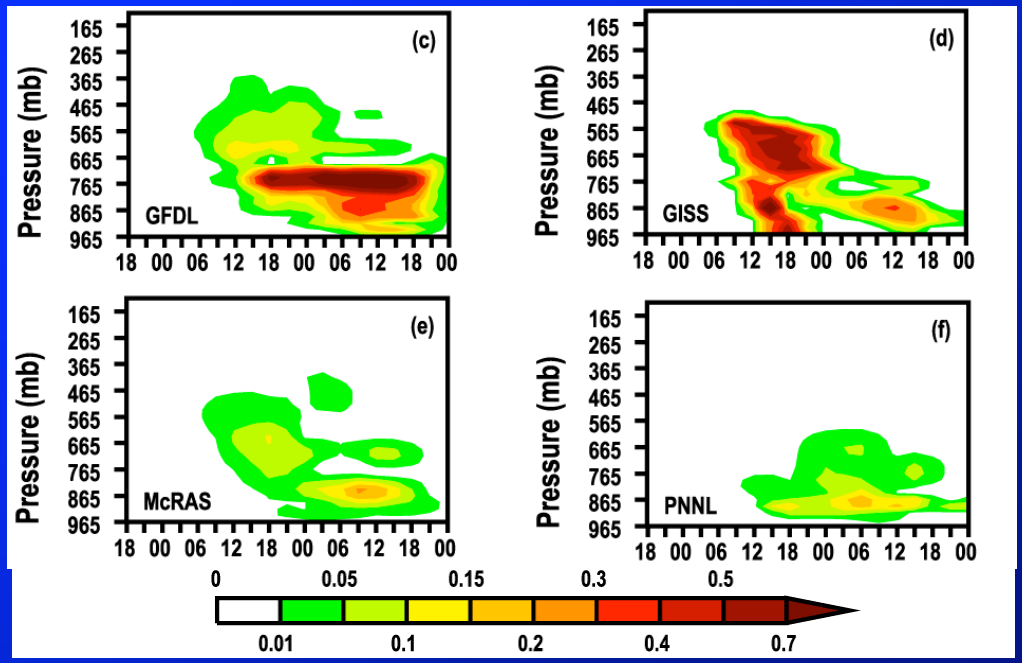
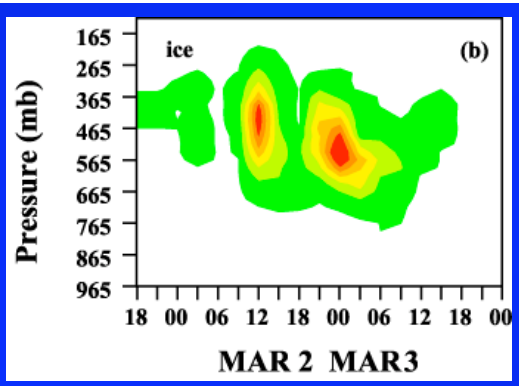


SCM liquid water varies a lot between models

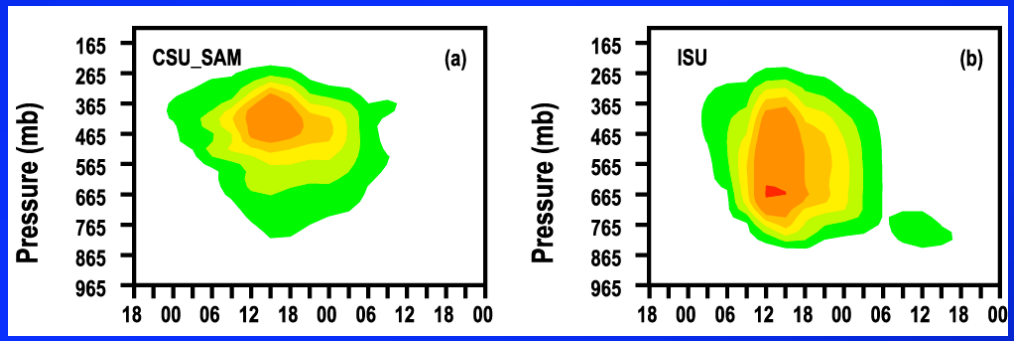
Cloud Ice

Observation



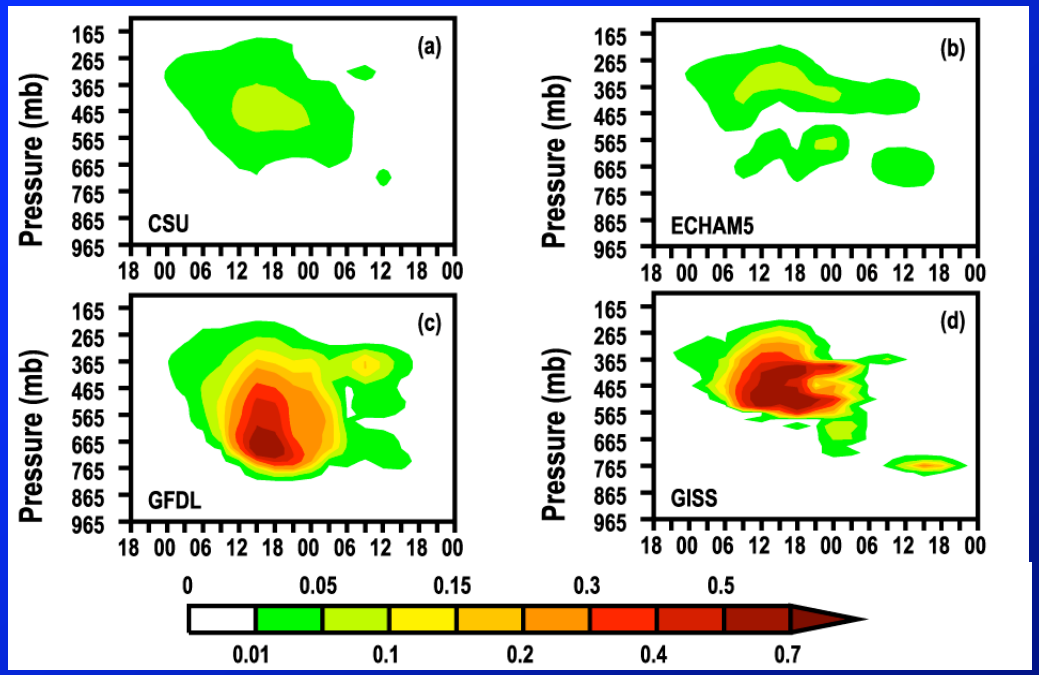
'Microbase' analysis courtesy of Mark Miller et al.

Selected CRMs



CRM ice water varies a lot between models

Selected SCMs



SCM ice water varies a lot between models

"Continuous" Forcing

(Xie et al. 2004)

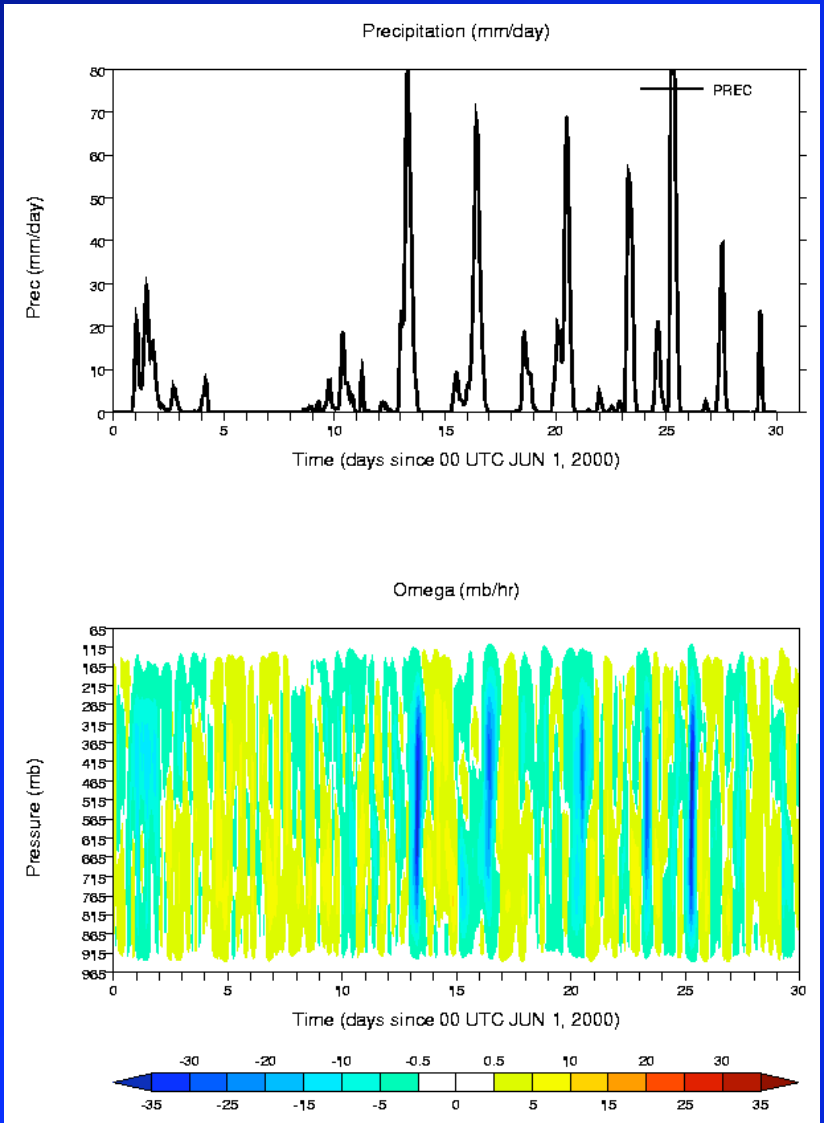
The Variational Analysis forcing is so nice, wouldn't it be great if it weren't limited to ARM IOPs?

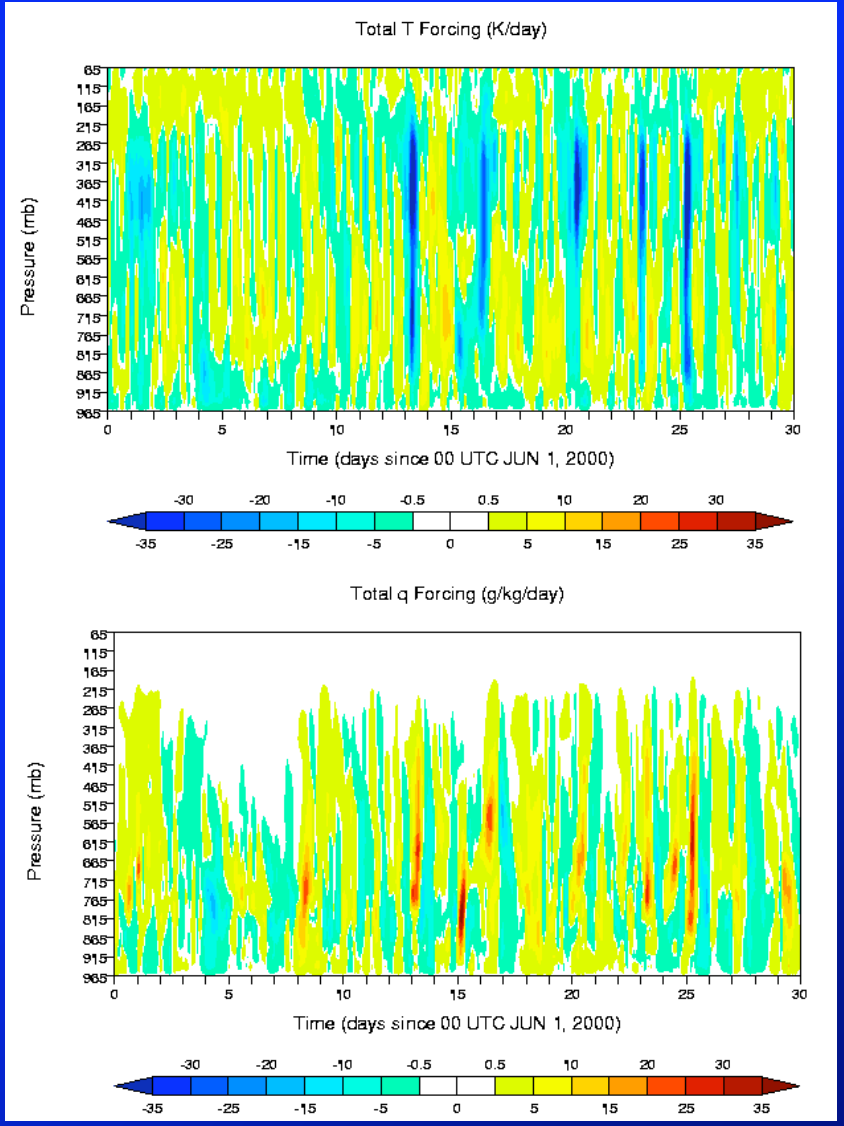
Yes!

If we do this, what observations would you miss? Primarily the radiosondes… but it is still worth doing (and produces forcing which is superior to NWP output – at least in summer).

Three years have been completed – 1999 - 2001

June 2000 “Continuous” Forcing





Examples of "Continuous" Forcing Uses

Build statistics! Move beyond case studies!

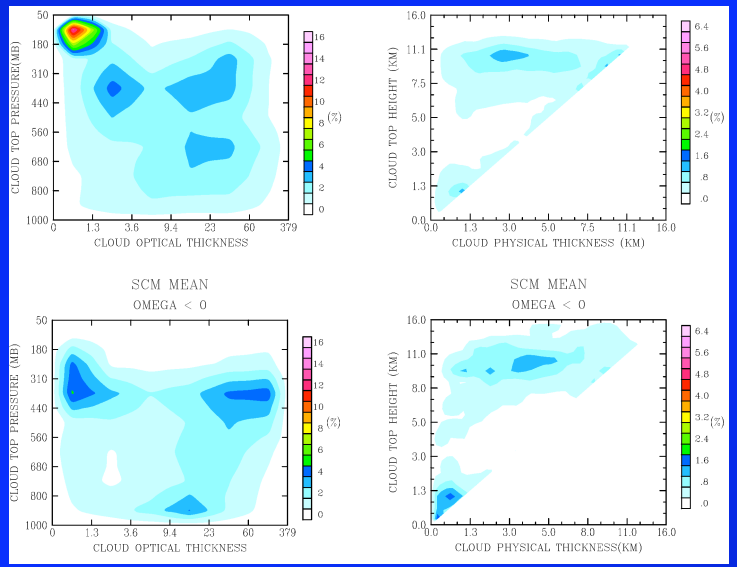
From the JGR Special Issue of the ARM CPM Working Group:

Gordon et al. 2005, *"Cluster analysis of cloud regimes and characteristic dynamics of midlatitude synoptic systems in observations and a model"*

Del Genio et al. 2005, *"Evaluation of regional cloud feedbacks with Single Column Models"*

500 mb Ascent

ISCCP ***Cloud Radar***

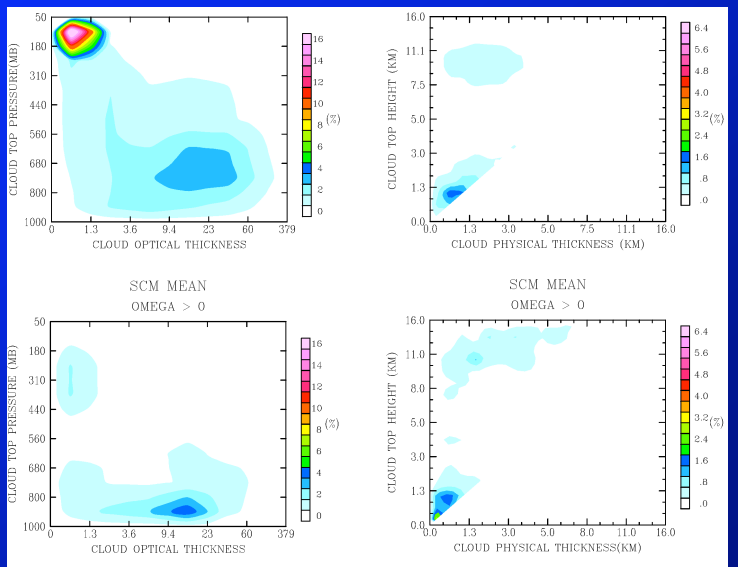


Observations

GISS SCM

500 mb Descent

ISCCP ***Cloud Radar***



Broad-Band Heating Rate Profile Project (BBHRP)

Eli Mlawer, Mark Miller, and many others, …

"So the first question that we need to answer is: Given a specified three-dimensional field of cloud properties, can we compute with sufficient accuracy the solar and terrestrial radiative flux transfer and associated atmospheric heating rates through the clouds?"

Ackerman and Stokes, *Physics Today*

- The goal is to derive the vertical profile of radiative heating rates over the ARM site continuously given all of ARM measurements and TOA satellite fluxes
- First do locally to the Central Facility, then extend to the whole ARM SGP site
- Uses the best ARM measurements of aerosol optical depth, LWP, etc.
- Radar clouds and the retrieved cloud micropohysics are key
- Focussed on the period 1999-2001
- First at central facility, then whole SGP domain, then other ARM sites

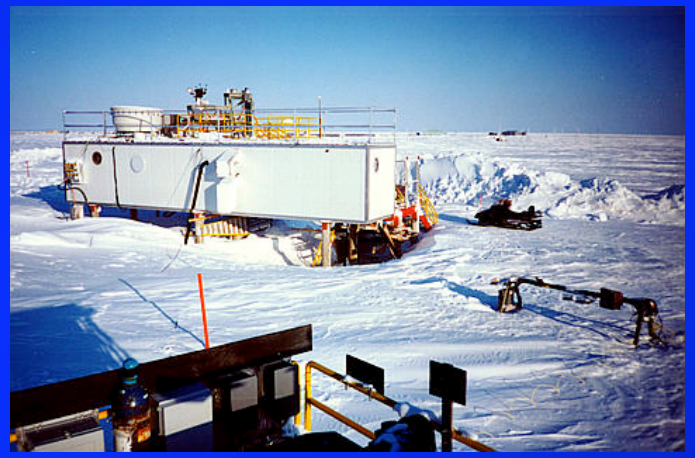
ARM Field Projects

Mixed Phase Arctic Cloud Experiment (MPACE)

North Slope of Alaska

October 2004

◊ see upcoming talk by Hans Verlinde



Tropical Warm Pool – International Cloud Experiment (TWP-ICE)

Darwin Australia

January – February 2006

◊ see upcoming talk by Jim Mather

ARM Mobile Facility Deployments

Marine Stratus Radiation Aerosol and Drizzle (MASRAD)

California Coast

March – September 2005

RAdiative Divergence using AMF, GERB, and AMMA STations (RADAGAST)

Niamey, Niger

~ January – December 2006

The End

Case 3 RMS T, q, and RH errors